UDC 666.1.022

OPTIMIZATION OF THE PHYSICO-CHEMICAL PROCESSES OCCURING DURING THE PREPARATION OF GLASS MIX AND EVALUATION OF THE EFFECT OF THE MIX MOISTURE CONTENT ON THE EFFICIENCY OF THE GLASS-MAKING PROCESS

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Translated from *Steklo i Keramika*, No. 8, pp. 19 – 23, August, 2010.

The physico-chemical processes and individual factors affecting the uniformity of the mix both when the mix components are being mixed in a mixer in a sectional line and when the mix is transported and loaded into a glass-making furnace are analyzed. The effect of moistening on mix quality in obtaining glass mix and transporting and loading the mix into the furnace by means of mix loaders is determined. The temperature factors ensuring that the mix temperature when the mix is loaded into the furnace is no lower than 35 – 40°C are determined. The degree to which mix is removed with respect to both quantity and individual components on the loading hopper and regenerators along the glass-making furnace is determined. The direction for further research on optimizing the mix preparation process in order to increase the operational efficiency of a glass-making furnace is proposed on the basis of the results obtained in the present work.

Key words: mix moisture content, mix temperature, mix uniformity, mix quality.

The strong competition in the glass market places high requirements on the indices of sheet glass, the most important of this are:

– high optical indices (zebra, grating, and others);

– high light transparency of glass (light transmission > 90%);

– stability of the quality indicators of glass with respect to foreign inclusions (bubbles, mix stones, and others) for their minimal content.

The mix plays a determining role in the production of glass with requirements imposed on these indicators. Of course, to produce high-quality mix it is necessary to have high-quality raw materials, modern batching and mixing equipment, and much else. We shall examine the effect of the mix moisture content on the processes involved in the production of mix, transporting and loading mix into a furnace, as well as on the processes occurring in a glass-making furnace.

The process of moistening a mix for glass-making and the role of water participating in the process have been studied in depth for many years. However, many questions remain unclear and require study. Because of the development of modern technological processes and equipment, including mixers, transport equipment, and modern glass-making furnaces in glass production it is now possible to increase the efficiency of the glass-making processes by optimizing the use of the moistening agents when moistening the mix.

One of the most important questions is the optimal moisture content of mix from the standpoint of obtaining and preserving the uniformity of the mix before it is fed into a furnace. In addition, this question must be examined and investigated along tow main directions:

1) the mix preparation process from mixing components in mixers in the sectional subdivision of the plant, transport before the mix is fed together with cullet into the furnace from loader tables of the glass-making furnace [1];

2) processes occurring during glass making with a change of the mix moisture content.

We shall examine the first direction of investigation. An important part is determining the optimal moisture content of the mix during mixing of the mix components according to the formula in the mixers of the sectional subdivision of the plant and the moisture content of the mix loaded into the glass-making furnace.

In studying the question of moistening it was established that the main part of this process is not simply introducing a definite computed amount of water into the mix but rather finding a modern method of adding moisture [2].

Here the following play an important role:

– temperature of the raw materials;

– granulometric composition of the raw material;

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– water temperature for moistening;
– water flow rate and its stability;
– use of steam as a secondary moistening agent;
– method for feeding and mixing cullet and the constancy of its ratio to the mix;
– loss of moisture and lowering of the temperature of the mix as the mix is transported to the furnace.

The first state of the work on determining the effect of these factors on the mixing and quality of the mix was conducted under winter conditions with negative temperature outdoors (often below – 30°C). This prompted a careful analysis of the temperature factor in the mix production process.

The technological process of batching and mixing the components was perfected; it is practically identical for all works producing float-glass, and it is performed on modern batching-mixing lines [3]. At the present time most modern works are switching to obtaining mix from ready-made raw materials concentrates, which do not require further mechanical and heat treatment. For this reason, the raw material enters metallic hoppers, stored in cold dumps and silos, i.e., it assumes the outdoor air temperature. The dissolution and crystallization processes in moistened glass mixes proceed most actively at a temperature of the moistening water in the range 50 – 60°C. Taking account of the low temperature of the raw material introduced for mixing, during the winter it is necessary to increase the water temperature to 70°C and higher and often use steam to reach the prescribed mix temperature.

As already mentioned above, the water in the moistening process participates in the physical (ensuring mix uniformity) and chemical processes (chemical reactions between the mix components during mixing, transport, and glass-making).

So, at mix temperatures below 35°C soda ash absorbs moisture and the mix becomes dry. At mix temperatures 30 – 35°C moisture comes into contact with the soda ash, forming crystal hydrates. At mix temperature to 30°C soda crystals $Na_2CO_3 \cdot 10H_2O$ absorb all moisture present. At temperatures 30 – 35°C soda crystals $Na_2CO_3 \cdot 7H_2O$ are stable forms but the mix remains dry. However, at temperature 35 – 40°C the soda absorbs only a small quantity of water, forming $Na_2CO_3 \cdot H_2O$; the mix remains moist and permits the mix components to bond [4, 5].

In this connection, different factors were taken into account at the stage of determining the optimal moisture content in a mixer, the most important ones being:
– mix temperature after mixing;
– uniformity of the mix with respect to the composition of the components;
– questions of operating the mixer itself and the equipment for transporting the mix to the glass-making furnace.

The following was established:
– the optimal moisture content of mix after the mixer is 3.8 – 4%, which makes it possible to obtain a uniform mix and thus minimize the operating expenditures on repairing equipment used for mixing and transport, to lower the number and duration of preventative shutdowns for cleaning the equipment;

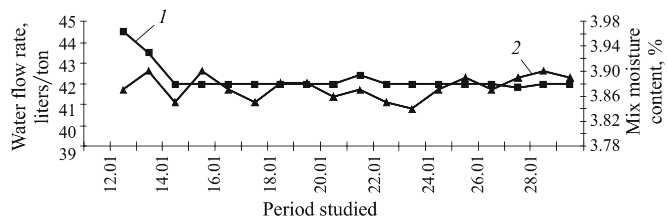

Fig. 1. Water flow rate per 1 t mix to maintain the optimal moisture content in the mix after the mixer in a sectional cell: *1*) water flow rate; *2*) moisture content of the mix.

– the minimal water temperature for moistening corresponds to 60 – 70°C, and during the winter above 70°C (since ready-made cold raw materials are used steam must be used);
– moisture content below 3.5% increases dust generation during technological changeovers, degradation of the mix uniformity in the mixer and additional separation during transport to the loaders of the glass-making furnace;
– mix moisture content higher than 4.5% complicates the mixing of the mix components and servicing of the equipment (shutdown for preventative cleaning of the mixers, elevators, and so forth); for prolonged storage (4 – 5 h) caking of the mix occurs.
– the amount of water required to maintain the optimal moisture content 3.8 – 4.0% in the mix after the mixer is about 42 liters/ton mix (Fig. 1).

We shall now examine effect of transporting mix from the mixer of the sectional subdivision of the plant to loading into the glass-making furnace on the mix's uniformity and moisture content.

The process of transporting mix is different in different glass plants. In modern, new plants the distance of these transport flows is negligible and equal to several tens of meters. In other plants, especially old ones, even after reconstruction the length of the transport flows is considerable and ranges from 100 to several hundreds of meters.

Let us examine the process of transporting mix by means of belt conveyers of two float-lines with different distance from the mixers to the point loading into the glass-making furnace. The path length is 206 m for line No. 6 and 393.5 m for No. 1.

When mix is transported over such distances, separation of the components occurs, i.e., uniformity is disrupted, moisture content decreases, the mix temperature decreases, and crystal hydrates form under certain conditions [5].

The factors affecting these indicators and lowering the quality of the prepared mix have been established. Here are some of them:
– considerable distance of mix transport from the mixer of the sectional subdivision of the plant to the loaders of the glass-making furnace;

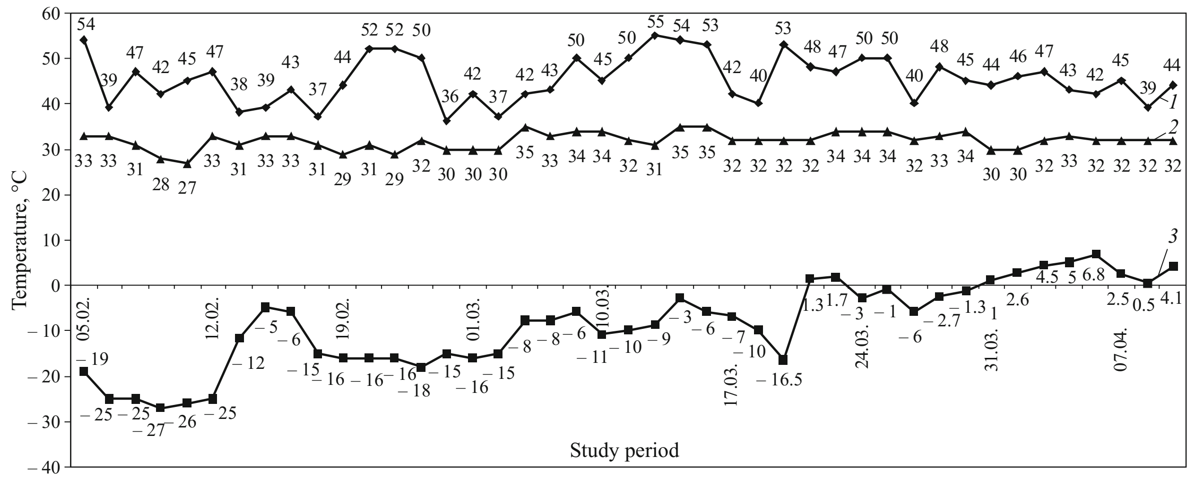

Fig. 2. Variation of the temperature during transport of mix to the furnace over a distance of 393.3 m: *1* and *2*) temperature of the mix after the mixer of the sectional subdivision of the plant and in front of the loader, respectively; *3*) outdoor air temperature.

– low temperature of the surrounding environment, including in the room were the mix is transported, and dependence of the temperature of seasonal factors;

– presence of substantial transfers of the mix (elevators, hoppers, leaks, depressants, and others).

It has been established that when mix is transported during the winter the temperature of the mix decreases from 55°C after the mixer of the sectional subdivision of the plant to a temperature below 30°C in front of the loader into the furnace and during summer it ranges from 60 to 40°C, respectively (Fig. 2).

At these temperatures the moisture content of the mix decreases by 0.20.5% in the winter and 0.5 – 1% in the summer (Fig. 3).

The temperature in the transport room during the winter was about 10°C and lower, and it decreased to – 1.0 ... – 5.0°C on individual sections. During this period with the mix at temperature below 30°C, as mentioned above, conditions are created for the formation of crystal hydrates in the moistened mix [4], which imparts to the mix properties of a bulk material and intensifies the separation of the mix and degrades its uniformity [5].

When cullet is added to such a mix and the new mixture is transfer into receiving hoppers of the loaders, the culler becomes nonuniformly distributed in the mix volume and correspondingly over the width of the loading hopper of the glass-making furnace.

The study of processes occurring during the transport of the mix from the mixers of a sectional subdivision of the plant to the location where the mix and cullet are loaded into the glass-making furnace made it possible to draw the following conclusions:

– the previously determined optimal, for the conditions of mixing in mixers of the sectional subdivisions of the plant, moisture content of the mix under these conditions is clearly inadequate for maintaining the uniformity of the mix along the entire transport path and for forming the molten glass in the furnace; it was determined that for the maximum moisture content prior to loading into the glass-making furnace 4.0 – 4.2% the moisture content of the mix on the tables of the loaders is only 3.4 – 3.6%; according to data obtained by I. Grebenshchikov, M. Fanderlik, and D. Shelby the optimal moisture content for glass-making is 5 – 7.0% [1, 2].

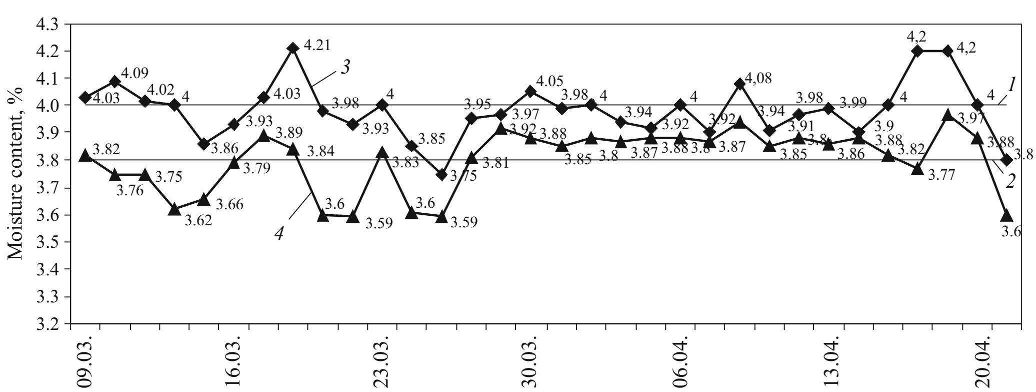

Fig. 3. Moisture content of the mix before loading into the furnace: *1*, *2*) maximum and minimum prescribed moisture content, respectively; *3*) moisture content in a sectional subdivision of the plant; *4*) moisture content in front of the loader.

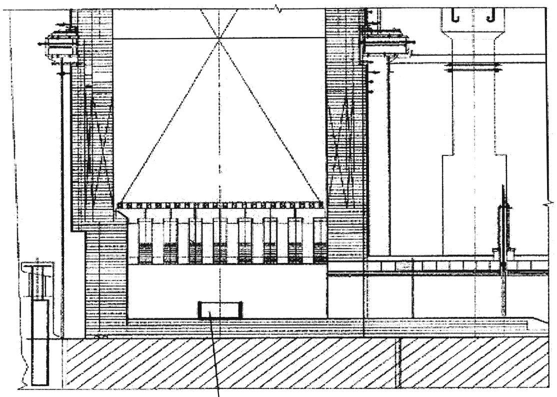

Fig. 4. Special bottom trays in the chambers of the regenerators of a glass-making furnace for measuring the removal of mix dust.

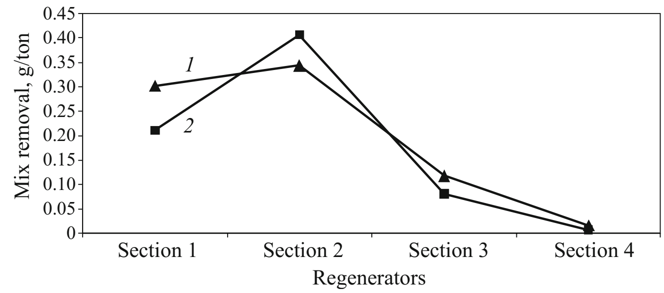

Fig. 5. Variation of the mix removal in sections of the regenerators along the furnace: *1* and *2*) on the right and left sides, respectively.

– the mix temperature decreases to 20°C, which decreases the uniformity of the mix, results in additional energy consumption for melting the glass in the furnace; the formation of crystal hydrates in carbonates in the mix lowers the uniformity of the mix and increases its flowability;

– the cullet added to dry dehydrated mix, becomes nonuniformly distributed in the mix volume in the hoppers of the loaders.

The processes occurring in the glass-making furnace with a change of the moisture content of the mix were studied in parallel.

When finding the moisture content in the batching-mixing subdivision of the plant factures influencing the quality of the glass, the operational efficiency of the furnace, and furnace run time such as the following were studied:

– removal of the component of the mix in different sections of the furnace;

– thermal efficiency of glass making.

The melting capacity is all the higher, the larger the surface area of the mix; the melting process and the quality of the melt in a tank furnace are largely determined by the form of the mix surface. When mixes with moisture content less than 3% are fed into the furnace, it is impossible to obtain the required layer formation, the boundaries of the layers fall apart, and an essentially even carpet of mix enters the furnace. As the moisture content in the mix increases, the layers formed by the loaded become sharper, thereby increasing the surface area of the mix.

The mix layer adjoining the glass melt is heated more rapidly than the layer adjoining the gas space.

The mix gases formed as a result of the reactions on the hot melting front of the bottom surface of the mix penetrate into the porous layer of the mix and flow upwards along cavities. They heat mix articles in their path. Thus, the transfer of heat from the melt to the mix is approximately 3 – 4 times greater than from the gas space of the furnace [3].

Of course, the attainment of mechanical uniformity of the mix guarantees maximum efficiency of the melting. The separation of the mix has a negative effect on the heat penetration through and fining of the melt. The moisture content prevents separation of the mix, since water acts as a binder owing to the appearance of capillary forces. However, these processes have been studied mainly with moisture content of mix fed into a glass-making furnace 2.5 – 3.0% (the standard moisture content of the mix after the mixer was 3.5 – 4.5%).

There exists the opinion that during melting of mix the evaporation of additional moisture can result in additional losses of energy [6]. But the study of the effect of water on the acceleration of chemical reactions of the mix components, increase of the uniformity of the mix, the temperature of the mix, and improvement of the contact (cohesion) of the components of the mix and cullet, the uniformity of the culler distribution in the moist mix shows that all this taken together results in acceleration of the glass-making process and a decrease of the energy expenditures.

It is known that during the production of glass the removal of mix components at different stages is one of the negative factors. It can be separated into losses which appear during the production of the mix and losses during loading of the mix into the furnace and during glass-making.

Factors such as the following are important when studying the effect of the moisture content on the removal of mix components when the mix is loaded into the glass-making furnace and in the glass-making process:

– airtightness of the loading hopper;
– form of the aspiration system on the loading hopper;
– granulometric composition of the mix components;
– gas pressure in the glass-making furnace;
– construction and volume of the regenerator checker;
– operating time of the furnace and checker;
– productivity of the furnace.

Work was performed on determining the removal in quantitative sense along the sections of the regenerators of a glass-making furnace and with respect to the components of the mix.

For this, a method of measuring the removal using special bottom trays placed in the chambers of the regenerators of a glass-making furnace was developed (Fig. 4).

The data on the amount of mix removed along the sections of the regenerators are presented in Fig. 5.

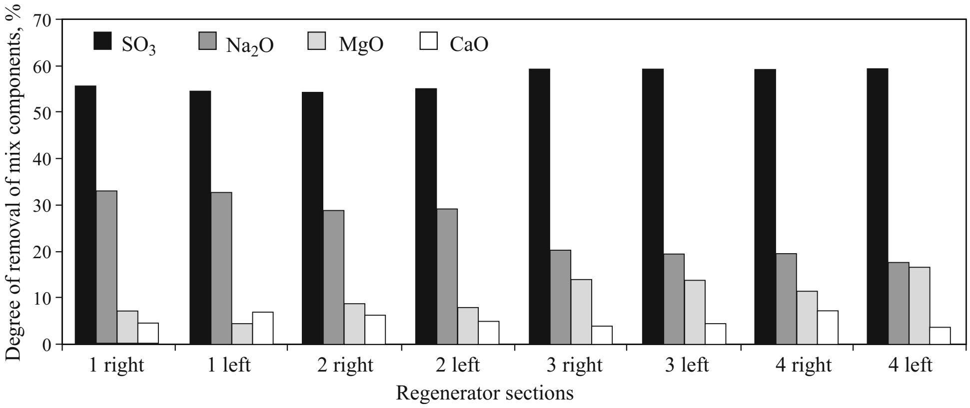

Fig. 6. Degree of removal of the component of a mix from subchecker chambers of the regenerators along sections.

The data on the degree of removal of the mix from the sub-checker chambers of the regenerators are presented in Fig. 6.

The amount of mix removed as a result of the measurements in the loading hoper of the furnace in the volumes of the right and left sides of the aspiration system, placed above the mix loaders, was also determined. The removal of mix ranged from 5 to 20 g/ton of the mix from with side of the loading hopper. Analysis of the composition of the removal of mix components from the filters of the loading hopper from the left and right sides of the aspiration system showed the presence in it from 46 to 65% of the carbonate component of the mix (dolomite + technical-grade chalk) and from 4 to 6% of soda with virtually no heavy fractions of the mix (sand, feldspar).

In summary, having examined the processes involved in the preparation of mix in mixers of a sectional subdivision of the plant and the processes of transporting during loading of the mix into the furnace and glass-making, certain conclusions can be drawn:

– the attainment of optimal quality parameters of the mix in the batching-mixing subdivision is not enough and does not give the required quality of the mixture consisting of mix and cullet on the tables of the loaders of a glass-making furnace and in the furnace itself;

– the results of the investigations of the existing technological process of preparing mix were used to determine the direction of further work and preparative work was done, directed toward eliminating the existing deviations.

Only certain questions for investigation and an analysis of the mix preparation process were examined in the article. At the same time some of the factors affecting the mix quality as well as the operating efficiency of a glass-making furnace and the improvement of the quality of sheet glass were determined.

To solve these problems it is necessary to continue studying these processes and eliminate step-by-step the deviations found in the mix preparation process.

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